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Influence of learning Physics by reading and learning Physics by doing on the Shift in Level of Scientific Reasoning

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ABSTRACT

The study observes two groups of high school students exposed to two different methods of teaching: the first group (N=181) learning physics by reading (LPLR) and the second group (N=170) learning physics by doing (LPD). This study investigates the influence of two different methods of teaching/learning on increasing the level of scientific thinking and uses the Lawson test of scientific thinking for that purpose. Our data indicate that the first group (learning physics by reading) achieves a normalized gain G=0.16, while the other group achieves G=0.31 on the Lawson test within a one semester long project. A particular attention was paid to the transition of concrete thinkers into higher levels of thinking within individual groups. For group LPLR it is 24% while for group LPD it amounts to the significant 44%. Aware of the factors that influence the increase of students' cognitive level, we allow the application of some useful interventions into the physics lessons in order to make them more productive for the students.

Keywords: Learning Physics by Reading; Learning Physics by Doing; Levels of Scientific Thinking; Concrete Thinkers.

INTRODUCTION

Scientific reasoning is at the heart of all evidence-based knowledge. The literature offers many definitions of scientific reasoning. From the perspective of scientific literacy (Giere, Bickle & Mauldin, 2006; Hazen & Trefil, 1991), scientific thinking refers to cognitive skills required for understanding and evaluating scientific information, often involving the understanding and assessment of theoretical, statistical, and causal hypothesis.

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In her framework for studies of the development of children's scientific reasoning, Zimmerman states that scientific thinking involves 'the thinking and reasoning skills that support the formation and modification of concepts and theories about the natural and social world' (Zimmerman, 2005) and claims that scientific reasoning ‘includes the skills involved in inquiry, experimentation, evidence evaluation, and inference that are done in the service of conceptual change or scientific understanding’ (Zimmerman, 2007).

Some philosophers (Kuhn, 1993, 1996; Lakatos, 1993) emphasize the importance of 'paradigms' (Kuhn) and 'research programs' (Lakatos) in science. This orientation towards science accepts traditional hypothetico-deductive methods and experimental evidence, but it also attaches importance to the collective application and confirmation of such evidence as reflected in shifts in paradigms and research programs.

Previous Studies

Important goals of science education should be to enhance students' (a) understanding of the basic concepts of science, and (b) ability to reason scientifically. In fact, the studies of Epstein (2000), Coletta and Phillips (2005), and Colletta, Phillips, and Steinert (2007a, b) suggest that, for many student populations, the degree to which objective 'a' is attained may depend on the degree to which objective 'b' is accomplished.

Among articles which demonstrate that advanced thinking skills are positively correlated with superior conceptual understanding are Johnson and Lawson (1998), Lawson (1980), Sadler and Zeidler (2005), Zohar (1996), and Zohar and Nemet (2002).

According to Piaget's model of cognitive development, an individual progresses through discrete phases and with time develops ability for scientific reasoning (Renner and Lawson, 1973a, b). Students go through different phases of development until they reach the highest level of scientific reasoning – formal-operational reasoning.

Between the age of 6 and 11, students reach the level of concrete-operational operations. At that stage, students can classify objects and understand conservation (of number, weight and continuous values), but they are still not capable of thinking in terms of hypotheticals (Inhelder & Piaget, 1958). Students only display hypothetical reasoning in the last stage in the development of reasoning, formal-operational reasoning. It is then when they can isolate and control variables and observe their interrelationships, e.g. proportional reasoning (Lawson, 2000). According to Piaget, students reach this stage at an age between 11 and 15.

But many researchers have shown that large numbers of high school and university students have not yet reached the level of formal operations (Elkind, 1962; Towler & Wheatley 1971). For example, Arons and Karplus (1976) state that accumulating evidence shows that as only 1/3 of the U.S. population in the age range 13 - 15 have reached the formal-operational level of reasoning. Most are limited to concrete-operational or transitional stage reasoning, i.e. partly capable of formal-operational reasoning. In other studies, with emphasis on the students of physics, similar results are obtained (Cohen, Hillman & Agne, 1978; Lawson & Renner, 1974; McKinnon & Renner, 1971). In his study Maloney (1981) showed that in the calculus and algebra based physics courses for science majors at Creighton University, 2/3 of students reach the level of formal operations, while in the courses that served education and health science majors hardly 1/3 of students reach that level.

The ways in which scientists develop their thinking skills, defend their conclusion, and deal with alternative explanations (Hogan & Maglienti, 2001; Nersessian, 1995) are frequently missing in science classrooms. Boudreaux, Shaffer, Heron, and McDermott (2008) studied students' understanding of the control of variables, and pointed out some serious educational challenges in that area. Many science teachers presume that their courses will advance students' scientific reasoning without students' personal participation in the scientific process (Hogan & Maglienti, 2001).

Such teachers evidently think that lecturing students on scientific facts and concepts or subjecting them to rote manipulation of laboratory apparatus will advance their scientific reasoning. Then those same teachers are surprised when students encounter difficulties in writing lab reports or applying the acquired knowledge to new experimental situations.

Thus it would appear that the improvement in scientific reasoning skills should be a specific and explicit goal of science teaching, as in the following programs:

a. 'Teaching for Proportional Reasoning' (Kurtz & Karplus, 1979);
b. 'Cognitive Acceleration' (Adey & Shayer, 1994; Adey, Shayer & Yates, 2001; Adey, 2004; Shayer & Adey, 2002; Shayer & Adhami, 2010);
c. 'Instrumental Enrichment' (Feuerstein, Rand, Hoffman, and Miller, 1980; Feuerstein, Klein and Annenbaum, 1991; Ben – Hur, 1994; Tribus, 1999);
d. 'Thinking in Physics' (Coletta & Phillips, 2009).

The latter program, as well as the previously referenced work by Coletta, Phillips and Steinert, utilized Lawson's Classroom Test of Scientific Reasoning (LCTSR) to assess students' progress in reasoning. The LCTSR has long been used in biology education and has proven to be consistently reliable (Schen 2007; Lawson, Banks & Logvin, 2007).

This study addresses one main issue; namely, the research task was to measure how two different methods of learning change (increase) the level of scientific reasoning. In order to obtain the necessary data we developed the following methodology.

METHODOLOGY

This research was conducted on the sample of senior students (17 – 18 years) in the last grade of a high school in Split (Croatia) in the academic year 2009/10. The total number of students that took part in the research was 475, out of which 297 were females and 178 were males. They all came from 16 different classes of the high school.

To determine the level of scientific thinking of students we applied The Lawson's Classroom Test of Scientific Reasoning (LCTSR) (Lawson, 1996) which was administered at the beginning and at the end of the project. The test consists of 24 questions. The questions refer to several areas: inferences about preservation, concluding about proportions, identification and control of variables, understanding probability and hypothetical – deductive reasoning. All of the above mentioned areas determine the level of students' scientific reasoning.

The total score on the test is 12. Considering the total score the following classification is given (Lawson, 1995):

0 - 4 points - **level of concrete operations**;
5 - 8 points - **transitional level;**
9 - 12 points - **level of formal operations**.

As a measure of gain on the post-test in relation to the pretest we are going to use G-normalized gain (Hake, 1998) defined by the relation

$$G = \frac{\text{postscore\%} - \text{prescore\%}}{100 - \text{prescore\%}}.$$

This parameter is widely used and interpreted as a measure of what a student or a group of students achieve in relation to what they could have achieved (Hake, 1998, 2002; Meltzer, 2002).

a) Study Design

The research task was to measure how two different methods of learning (*learning by reading* and *learning by doing*) change (increase) the level of scientific reasoning.

Students in high school have a standard set of topics that are set by the annual syllabus. Number of hours of physics in high school is 2 hours per week. Within the obligatory physics curriculum (Paar, 2006), there is some time allocated to the free topic formation, limited to one hour per week. This means that apart from the topics set by the syllabus the teacher is allowed to introduce some additional ones that may reflect his/her or preferably students' interests.

The research lasted one semester (spring semester). This period is particularly suitable for conducting the project because the students are in the last semester of their high school education and already possess certain knowledge from different scientific areas as well as attitudes towards them. These included 12 lessons for treating the chosen topics and 4 for pre and post assessments. The free topics were chosen by researchers and students.

b) The first group: learning physics via lecture and reading (LPLR)

For the first group (6 classes or 181 students), the teaching was delivered by introducing some of the current topics related to the recent scientific discoveries in physics. The method of teaching/learning applied in the process is characterized by

(i) students' autonomous reading/study of popularizing articles suggested by the teacher - researcher (the first author),

(ii) reading/study of some obligatory internet resources and some on-line resources the students found by themselves and

(iii) PowerPoint™ presentation of the learning results.

The two examples were chosen to illustrate the ways in which modern science has gained new knowledge. These are:

1. Large Hadron Collider (LHC) at CERN (6 lessons)
   - One huge experiment, Compact Muon Solenoid (CMS), was studied in detail along with its potential and technologies developed for the purpose.
2. Wilkinson Microwave Anisotropic Probe (WMAP) (6 lessons)
   - A detailed analysis was performed of how the experiment was conducted, how data were organized and what were the major findings,
   - Other experiments that confirmed the results of WMAP were mentioned (Method supernova Ia...).

This teaching/learning design also involved breaking down bigger groups of students into smaller ones, with the purpose of encouraging discussion and further analysis of the suggested topics from the field of contemporary physics.

Three teams that consisted of approximately the same number of students (8 to 11 students) were formed in each class:

- The team with the task of presenting the problems and questions that arise from the first topic,
- The team with the task of presenting the problems and questions that arise from the second topic,
- The team with the task to critically analyze the above mentioned presentations.

The students chose the groups themselves depending on their interests as well as the level of proficiency in physics. The teacher appointed a team leader who was in charge of distribution of reference materials and preparing the group for their role in the project – presentation on the given topic (Slavin, 1992, 1996; Johnson & Johnson, 1999).

The final aim was to encourage a discussion among the students' groups which would reveal the cognitive processes, emotions and motivation.

This part of the research started by the lecture given by a professor of physics (Ivica Puljak, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Croatia) who is a member of the actual Croatian research team at CERN. The lesson served to inform students about all the relevant facts of the CERN project to the extent to which the students were interested. The students were also given the opportunity and encouraged to ask questions. A significant interest in the project on behalf of a number of students was noticed, as well as a lively communication with the scientist who personally took part in the mentioned project.

The following 8 hours/lessons were dedicated to the presentation of the contents by the subject teacher who used standard lectures aided by a number of visually rich PowerPoint™ presentations. The students used their notebooks to record important information and particular characteristics of each experiment. No particular discussion was noticed among the students in this period, although the teacher tried to answer all the students' questions.

The seating arrangement was strictly set and it was the teacher - researcher who always conducted the lesson and controlled the classroom atmosphere.

The last three project lessons were reserved for student presentations which were allocated in advance. Each group appointed a representative who coordinated the group performance and made sure that each member of the group expressed his/her problems and impressions that emerged in course of the previous physics lessons. Each group was allocated one lesson for presenting their findings about the studied topic. The group representative and several members of the group appointed by the representative presented their views to the rest of the class. Finally, in the final lesson of the project, the critics group was asked to prepare a debate for all the students and the subject teacher. The debate triggered a number of interesting opinions about the project and the studied topics.

c) The second group: learning physics by doing (LPD)

The teaching/learning process for the second group (6 classes or 170 students) was based on treating the traditional – "old" topics but in a new way, applying the didactics of active learning, i.e. the learning where the student is an active participant of the process revising old and gaining new knowledge.

As it is widely known, some of the sequential tasks which promote active learning are

(1) Predict – Observe – Explain (White & Gunstone, 2001) or

(2) Observe – Explain – Predict – Test (Etkina, Van Heuvelen, Brookes & Mills, 2002; Van Heuvelen & Etkina, 2006).

These physics learning sequences activate the existent students' knowledge and test it by comparing the predicted and the observed. These sequences of active learning were carried out by using simple experiments to treat a limited selection of physical concepts and phenomena for which students usually have alternative concepts (Clement, 1993; Hammer, 1994; McDermott & Redish, 1999; Pfundt & Duit, 2006):

- Force and the concept of motion (4 lessons)
- Pressure (hydrostatic, hydraulic, atmospheric, hydrodynamic) (4 lessons)
- Heat (4 lessons).

The teacher organized the teaching process in such a way that one simple experiment was carried out every lesson. At the beginning of each lesson an experiment was described to the students without actually carrying it out. The students were asked to anticipate the possible results of the experiment. Both the predicted results and their physical explanation had to be noted down in their notebooks. Then, they were asked to give their own, personal explanations of the anticipated results. Once the possible results of the experiment were defined, i.e. when groups of students with the same "physical" views were formed, the students were able to debate and offer their explanations for the expected results. The debate allowed the students' preconceptions and the level of scientific reasoning to be clearly recognized by both the instructor and the students themselves.

After the debate the experiment was conducted and the results were observed and recorded. Surprising results of experiments always provoked students' delight and positive emotions. They often asked for the experiment to be repeated because they did not believe the result was possible. Naturally, the teacher then always required the students to carry out the experiment themselves. The experiments were followed by another debate based on the reasons for anticipating certain results of the experiment. This discussion, guided and helped by the teacher, led to the construction of a better physical explanation of the observed phenomenon.

The seating arrangement was informal, in particular during the experiment itself. The students wanted to be as close as possible to the place where the experiment was being carried out and they were also given the opportunity to do it themselves.

In the course of the project a greater participation of students in situations enabling obtaining new knowledge was noticed, as well as recognition of such situations in everyday life which enables the shift in previous conceptions of knowledge they possess. Student discussions about the observed physical phenomena were also noticed in out of class situations.

The students who were not active in regular physics classes often showed a great improvement in active learning sessions. We found that the students were able to direct the learning process themselves by their reactions and answers, and to seek improvement of their initial answers without fearing bad grades or reprimands.

d) Control group

In order to understand better the results of this study, we have to answer the following question: Is it possible that the natural improvement of students within one semester contributed to the gain on the Lawson test, independently on the method of teaching?

To solve that problem, a control group of the same school senior high school students was observed. The students followed regular classes and were not exposed to the methods of teaching/learning that were applied in the LPLR group and LPD group. Their lessons were organized exclusively through traditional teacher lectures from obligatory physics curriculum. They had no free physics topics.

As we said before, the total number of participants is broken down into three groups for the purpose of the experiment (Table 1).

Table 1. *Information for groups surveyed*

all students	**I group - LPLR (learning by reading)**	**II group-LPD (learning by doing)**	**Control group**
475	181 (38%)	170 (36%)	124 (26%)

The main aim of the study was to observe the shift in the level of scientific reasoning and not to assess students' content knowledge. Moreover, the physics free topics covered in the two groups were different and it was therefore impossible to have a completely objective instrument for comparing the shift in students' knowledge. This limitation to the current study presents an interesting issue which certainly needs to be addressed in one of the future studies.

FINDINGS and DISCUSSION

The results of the Lawson test application in Croatian high school education system have not been published yet, which makes this study the first one that gives an insight into the level of scientific reasoning of high school population in the Republic of Croatia.

Table 2 shows pre and post- results for all observed groups of students.

Table 2. *Pre and post-results of Lawson test for groups of thinkers for LPLR and LPD groups of students and for the control group.*

		Concrete	Transitional	Formal
LPLR group (%)	pre	26	57	17
	post	24	47	29
LPD group (%)	pre	27	53	20
	post	15	46	39
Control group (%)	pre	31	50	19
	post	29	52	19

Between the three observed groups (Table 2) there is no statistically significant difference in the results on the Lawson pre-test ($p>0.05$). The students at the formal level of reasoning account for the lowest percentage (16.5% for LPLR group and 20% for LPD group), students at the concrete level of reasoning account for a slightly higher percentage (26.4% for LPLR group and 27.1% for LPD group), while the transitional level accounts for the highest percentage (57.1% for LPLR group and 52.9% for LPD group). LPLR group has 4.2% more students on the transitional level than the LPD group, while LPD group has 3.5% more formal thinkers than LPLR group.

Pre-test results of the control group (Table 2) indicate that there are 31.3% of concrete thinkers, 49.4% of those on the transitional level, while 19.4% of them are formal thinkers. Post-test results for control group after one semester show that 29% of the students remain in the concrete thinkers group, 51.6% are on the transitional level while the percentage of the formal thinkers remaines the same. Results of the control group on the post-test are only slightly different from those on the pre test. It means that lecture-based teaching does not change students' scientific reasoning level significantly. Taking this fact into account, the results of the shift in scientific reasoning of LPLR and LPD groups will be thoroughly observed and evaluated.

Post-results of the Lawson test (Table 2) for the observed groups show significant difference. Post-results for LPLR group indicate that, after the project has been carried out, there are 24.2% of students which are concrete thinkers, 47.3% are at the transitional level, while 28.6% of them are at the level of formal reasoning. Post-results for LPD group indicate that, upon the end of the project, 15.3% of students are concrete thinkers, 45.9% are at the transitional level, and 38.8% of them are at the level of formal reasoning.

Improvement of the groups is given by the normalized gain G. For LPLR group $G = 0.16$ while for LPD group $G = 0.31$. So, for that group the gain is almost two times bigger (Figure 1).

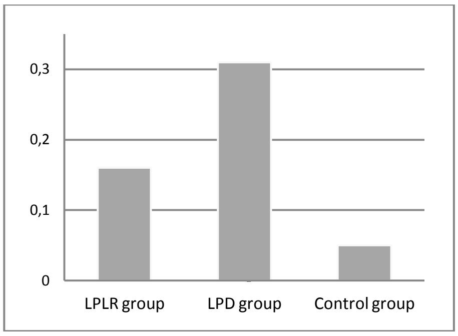

Figure 1. *G - factor for LPLR, LPD and Control group.*

G – factor for the control group is 0.05 which leads to the conclusion that within one semester of teaching using the traditional methods no significant changes in the level of students' scientific reasoning have happened.

It is interesting to observe migrations between different groups of thinkers.

Table 3. *Migrations of groups of thinkers within LPLR and LPD groups.*

POST / PRE	LPLR group (%)			LPD group (%)		
	Concrete	**Transitional**	**Formal**	**Concrete**	**Transitional**	**Formal**
Concrete	76.0	24.0	0.0	56.0	44.0	0.0
Transitional	7.8	72.0	20.2	0.0	64.0	36.0
Formal	0.0	0.0	100	0.0	0.0	100

Table 3 shows migrations of thinkers within LPLR group. In that group 76% of concrete thinkers remain at such level on the post-test while 24% of them shift to the transitional level. 72.0% of transitional thinkers remain at the same level on the post-test. 7.8% of them are degraded to concrete thinkers, while 20.2% of them are upgraded to the formal level of reasoning.

Observing migrations within LPD group (Table 3) it is evident that 56% of concrete thinkers remain within the same group. 44% of them shift into the higher level – transitional thinkers. 64% of transitional thinkers remain in the same group on the post-test while 36% of them are upgraded to formal thinkers.

There is no change in the groups of formal thinkers for either of the groups. All formal thinkers on the pre-test have remained in the same groups on the post-test.

Table 4 shows G – factor for each question of the Lawson test for individual groups.

Table 4. *G-factor by questions on the Lawson test for the LPLR and LPD groups.*

Question on the LCTSR	**1,2**	**3,4**	**5,6**	**7,8**	**9,10**	**11,12**	**13,14**	**15,16**	**17,18**	**19,20**	**21,22**	**23,24**
LPLR group	0.44	0.53	0.24	0.09	0.41	0.13	0.07	0.30	0.21	0.30	0.01	0.02
LPD group	0.85	0.91	0.39	0.25	0.61	0.25	0.15	0.43	0.25	0.44	0.11	0.06

LPD group obtains significantly higher G –factors in relation to the LPLR group in all questions of the Lawson test. It is particularly significant for the questions related to Conservation of weight (question 1,2); Conservation of displaced volume (question 3,4);

Identification and control of variables (question 9,10); Identification and control of variables and probabilistic reasoning (question 11,12); Advanced probabilistic reasoning (question 17,18); Correctional reasoning (includes proportions and probability) (question 19,20).

Table 5. *Presentation of the relation between the sum of points on the pre and on the post Lawson test; presentation of the pre and post groups of thinkers within LPLR, LPD and control groups*

SHIFT	LPLR group (%)			LPD group (%)			Control group (%)		
	a	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
Sum of points	6	60	34	2	90	8	13	31	56
p value	0.000			0.000			0.034		
Groups of thinkers	4	19	77	0	31	69	5	7	88
p value	0.005			0.000			0.480		

a. posttest < pretest, **b.** posttest > pretest, **c.** posttest = pretest

Observe the shift in scores on Lawson test by group shown in Table 5. In LPLR group 6% of students have decreased the total score on the post-test, 34% of students have the same pre and post- results, while 60% of students have better results on the post-test. These results are statistically important (p= 0,000).

In LPD group 2% of students have lower results on the post-test, 90% of students show a positive shift, while 8% of them maintain the same score on the post-test. The shift in scores on the Lawson test for LPD group is statistically significant (p = 0.000).

Results by groups of thinkers (Table 5) indicate that in LPLR group 4% of students are downgraded into the lower group of thinkers, 19% of students are upgraded to the higher level of thinkers, and 77% of students remain within their original group and these results are statistically significant (p = 0.005).

In LPD group there are no students who move to the lower levels of thinkers, 31% of students move to the higher level while 69% of them remain in the same group as at the beginning of the project. The shift in the group of thinkers in this group of students is statistically significant (p = 0.000).

Table 5 also shows the results for the control group related to the shift in score on the Lawson test as well as for the shift in the group of thinkers. Although the shift in the score on the Lawson post-test is statistically significant ($p = 0.034 < 0.05$) there are no statistically significant changes in the migration between the groups of thinkers (p = 0.480).

What we are particularly interested in is the improvement of concrete thinkers in both observed groups of students. For the concrete thinkers of LPLR group G = 0.14, while for LPD group G = 0.27.

Since there is a problem of low level of scientific reasoning in the delivery of physics lessons, it is essential to observe which method of learning design enhances the level of scientific reasoning to a greater extent. The results show that there is no change in the formal group of thinkers. Therefore that group will not be considered in what follows.

The results, presented in the Figure 2, show the difference between post and pre results on the Lawson test for concrete and transitional thinkers.

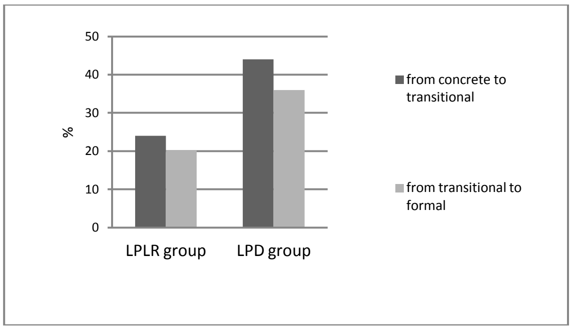

Figure 2. *Shift in the post and pre results on the Lawson test for concrete and transitional thinkers of LPLR and LPD groups.*

In LPLR group the shift of concrete thinkers into transitional is 24%, while 20.2% of the transitional group of students shift into formal thinkers.

For LPD group 44% of concrete thinkers shift into the transitional group of thinkers, while 36% of transitional ones shifts into the group of formal thinkers.

So, both shifts (concrete to transitional and transitional to formal) are much higher in LPD than in LPLR group.

Finally, besides the analysis of the migration of concrete thinkers towards higher levels of reasoning, it is also interesting to look at the change in scores on the post-test in relation to the pre-test, by groups, for students at the concrete level of reasoning. Figure 3 shows the change in scores on the post-test in relation to the pre-test for concrete thinkers of the LPLR group, while for LPD group those results are shown in Figure 4.

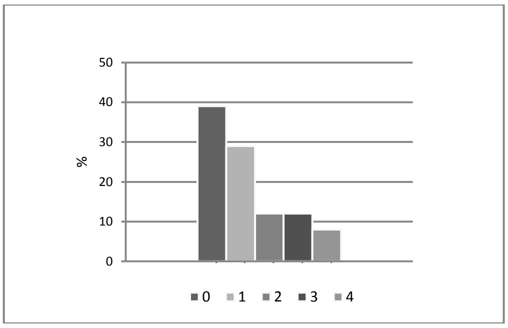

Figure 3. *Gain in points on the Lawson post-test in relation to the pre-test for concrete thinkers in LPLR group.*

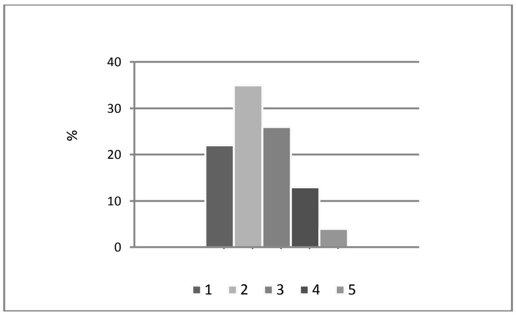

Figure 4. *Gain in points on the Lawson post-test in relation to the pre-test for concrete thinkers in LPD group.*

In LPLR group 39% of concrete thinkers have the same score on the pre and on the post-test, 29% of them show an improvement of one point, and 12% of concrete thinkers gain two points more on the post-test. The same percentage of 12% applies to the concrete thinkers who gain three more points on the post-test, while 8% of concrete thinkers have four more points on the post-test as compared to the pre-test.

For concrete thinkers of the LPD group there are no students who retain the same number of points on the post-test. 22% of them achieve an improvement of 1 point, 35% an improvement of 2 points, 26% have three points more on the post-test, 13% of concrete thinkers show an improvement of four points, and 4% of them have five points more on the post-test.

These results show that the LPD group has achieved a significant positive shift in the level of students' scientific reasoning and therefore confirms that “physics learning by doing” more favorable for gaining the goals of physics teaching, i.e. increasing the level of scientific reasoning in students.

CONCLUSION

This study has answered the research question by presenting the results of the evaluation of the level of scientific reasoning for the population of senior high school students and by analysing the shift in that level in dependence to the applied method of teaching. The study used the Lawson test of scientific reasoning and is the first of that kind in the Republic of Croatia. Pre-test results show that less than 20% of senior high school students are at the level of formal scientific interning. This might lead to poor acquisition of physical concepts for a great number of students, which in its turn leads to a problem in carrying out high-quality physics instruction.

It is a traditionally accepted belief among teachers and researchers that physics teaching, stressing logical and mathematical structures of physics knowledge, generally improves students' scientific reasoning. However, focus on mere acquisition of physics knowledge in the traditional format is not enough to improve reasoning abilities of students measured by the Lawson’s test, as was shown by one-semester results of the control group. The physics courses in Croatian elementary schools, high schools, and institutions of higher education are mostly characterized by traditional lecturing methods of teaching.

Since these instructional environments affect what students can gain from those courses, it is essential that we seriously consider the goals and methods of physics education. Therefore, we need to inquire to what extent methods of teaching and learning might have a positive effect on students' cognitive abilities. Driven by that question, we studied results of two different designs of learning: LPLR (*new topics and learning by reading the reference materials*) and LPD (*old topics and learning by predicting, observing and explaining simple phenomena*) and their influence on the level of increase in scientific reasoning.

The results show that in the period of one semester (with 12 45-minute sessions) both methods brought about improvement in the levels of scientific reasoning. However, it is also evident that significantly better overall results are gained by those students who participated in the LPD environment. This also applies to the transition of students towards higher levels of scientific reasoning, particularly for students who were at the concrete infringing level. Results of the LPD group, which show that 44% of concrete thinkers shift to a higher level of reasoning, irrelevant of the sex of students, are comparable with the results gained in one of the best of the intervention programs in science education. Cognitive Acceleration through Science Education (CASE) reported results which range from 25% to 50% (Leo & Galloway, 1996; Shayer & Adey, 1992, 1993). It is important to emphasize that in the LPD intervention all students achieve a statistically significant improvement. It is exactly this fact that leads to the conclusion that LPD teaching is a good way to increase the level of scientific reasoning in a greater number of students which is an important prerequisite for improving the quality of physics learning.

Finally, we observed that two groups of students did two different things. It was shown that one design of learning (old topics and learning by predicting, observing and explaining) is more effective than the other one (new topics and learning by reading the reference materials) when one considers the improvements on the Lawson test.

Namely, the groups differ not only in the method of learning, but also in the topics studied. Future studies should compare both methods of learning (reading about physical concepts or acquiring physical concepts through minds-on and hands-on activities) when dealing with the same topics.

SUGGESTIONS

In the end, we would like to summarize several potentially useful messages for both teachers and researchers:

• Teaching and studying of knowledge contents in traditional format do not help students to develop scientific reasoning abilities. Gaining content knowledge and improving reasoning ability are two different categories which do not necessarily come together.

• New methods of teaching (learning) are necessary in order to help students develop the abilities of scientific reasoning.

• For a better and more complete assessment of students' achievement we should use more criteria, including content knowledge, scientific reasoning and others (e.g. affect, self-efficacy).

We believe this paper shows that if contemporary active methods are applied to teaching, students' level of scientific reasoning can be increased. Such teaching models should replace the traditional ones where a student is just a passive participant.

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